NOTES ON SOME IGNEOUS, METAMORPHIC, AND SEDIMENTARY ROCKS OF THE COAST RANGES OF CALIFORNIA.[1]

The metabasalts and diabases of the Coast Ranges.—There are very abundant masses of greenish rocks in the Coast Ranges which are often massive, but sometimes form distinct breccias. The microscopic investigation of these rocks show them to be of igneous origin, and to largely represent old lavas. Many such rocks were supposed by Professor Whitney, the former state geologist of California, to be metamorphic sandstones. Dr. Becker, in his investigation of the quicksilver deposits[2] of the Pacific slope, regarded some of them as metamorphic sandstones, and gave such the name "pseudo-diabase" and "pseudo-diorite." In an investigation of the geology and petrography of Mt. Diablo,[3] I found that some of the so-called metamorphic sandstone of Whitney was true diabase and unquestionably of igneous origin. In this conclusion, Dr. Becker concurred. More recently Dr. Ransome,[4] in a study of the rocks at Pt. Bonita, California, found there similar rocks, which he called basalt and diabase. Still later, Ransome, in an investigation of the geology of Angel Island, found certain greenstones which he considered as allied to fourchite, although admitting that feldspar might have been present in the rock, as indicated by the great abundance of a zoisite-like mineral in some thin sections.

In 1897, in company with Mr. J. S. Diller, I visited Angel Island and collected there specimens of the so-called fourchite, and of other rocks. Some of these specimens show plenty of fresh plagioclase and there is therefore no doubt that some of

[1] The author, doubtless due to absence in the field, has been unable to read the proof of this article.

[2] Mon. XIII, U. S. Geol. Surv. [3] Bull. Geol. Soc. Am., Vol, II, pp. 383–414.

[4] Bull. Dept. Geol., University of California, Vol. I, pp. 71–114.

this greenstone is a feldspathic rock, and not a fourchite. However, if we suppose that the pyroxene in the specimen analyzed by Ransome be an ordinary aluminous augite, and that all the magnesia of the rock is in the augite, a calculation shows that the rock contained about 80 per cent. of augite, so that in this specimen the feldspar must have existed in small amount. The specimens from the Angel Island fourchite area which I examined have the structure and composition of a holocrystalline basalt in which the augite shows an idiomorphic tendency, as it often does in modern doleritic basalts. The Angel Island greenstone may, therefore, be called in part a metabasalt, and this term should likewise be extended to the basaltic rocks at Pt. Bonita, inasmuch as in all cases the basalts have undergone extensive metamorphism. A comparison of the analyses of the spheroidal basalt at Pt. Bonita, with that of the fourchite at Angel Island, and of other greenstones from other portions of the Coast Ranges,[1] brings out very clearly the similarity in composition of these greenstones at widely separated localities.

ANALYSES OF METABASALTS AND DIABASES FROM THE COAST RANGES.

	I Fourchite from Fourche Mt.	II Fourchite from Angel Island	III Diabase, Pt. Bonita	IV Diabase, Pt. Bonita	V Spheroidal basalt, Pt. Bonita
Silica	42.03	46.98	45.59	46.28	49.45
Alumina	13.60	17.07	20.99	12.96	17.58
Ferric oxide	7.55	1.85	2.49	4.67	3.41
Ferrous oxide	6.65	7.02	4.36	6.06	3.41
Lime	14.15	12.15	7.57	10.12	7.20
Magnesia	6.41	8.29	8.95	8.71	4.05
Potassa	.97	.53	4.89	3.75	1.57
Soda	1.83	2.54			5.83
Analyst	Brackett and Noyes	Ransome	Ransome	Ransome	Ransome

1. Fourchite from Fourche Mountain, Arkansas. (Ann. Rept. Geol. Surv., Arkansas, 1898, Vol. II, on "The Igneous Rocks of Arkansas," by J. Francis Williams, p. 108.) This

[1] See table of analyses.

rock is composed of 75 per cent. of augite and secondary material, probably leucoxene, with a highly altered ground mass.

2. Fourchite from Angel Island. (Bulletin Dept. of Geol. University of California, Vol. I, p. 231.) Ransome.

3 and 4. Diabase from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

5. Spheroidal basalt from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

	VI Epidiorite-Potrero	VII Pseudo-diabase Mt. St. Helena	VIII Pseudo, diabase, Sulphur Bank	IX Diabase, Mt. Diablo	X Diabase, Mt. Diablo
Silica	47.41	49.08	51.28	51.58	52.06
Alumina	16.03	14.68	15.05	14.99	14.34
Ferric oxide	2.66	1.95	2.41	2.04	2.11
Ferrous oxide	7.05	9.63	8.01	8.36	7.74
Lime	12.33	10.09	7.08	8.59	8.05
Magnesia	5.81	6.69	6.07	6.51	9.26
Potassa	4.47	0.20	0.12	0.31	0.73
Soda		4.60	4.43	3.08	1.74
Analyst	Palache	Melville	Melville	Melville	Melville

6. Epidiorite Potrero. (Bulletin of Geol. University of California, Vol. I, p. 177.) Palache.

7. Pseudo-diabase from near Mt. St. Helena. (Monograph XIII, U. S. G. S., Becker, Quicksilver Deposits, p. 98.)

8. Pseudo-diabase, Sulphur Bank. (Mon. XIII, p. 99.) Becker.

9 and 10. Diabase from Mt. Diablo. (Bulletin Geol. Soc. Am., Vol. II, p. 412.) Turner.

Serpentine.—There are very abundant areas of serpentine in the Coast Ranges, single masses often covering many square miles. The occurrence of serpentine was noted by the geologists who accompanied the Pacific Railroad exploration parties, and the first analysis of a California serpentine which I have found recorded, is that given by Professor Newberry, and is of a specimen collected at the Presidio at San Francisco. Later,

Professor Whitney, in the study of the Coast Ranges, came to the conclusion that the serpentine originated from the alteration of sediments. Dr. M. E. Wadsworth,[1] who studied the Whitney collection of rocks, however, subsequently described some of the serpentines and pyroxenites and peridotites from serpentine areas in California, as probably being igneous rocks. Professor Whitney, under whose supervision Dr. Wadsworth worked, does not appear to have objected to this.

When Dr. Becker undertook the investigation of the geology of the quicksilver districts, the difficulty of accounting for the great change in chemical composition of any sediment to a rock with the composition of serpentine was very apparent. However, he found evidence of such alteration in the sandstones of what is now known as the Franciscan or Golden Gate series. Some of these sandstones contain igneous material, derived undoubtedly from preëxisting igneous rocks or from volcanoes of the Golden Gate period, and some of this igneous material undoubtedly has formed some serpentine. Indeed, needles of serpentinoid material were noted eating their way into grains of quartz, and such evidence led Dr. Becker to conclude that considerable masses of serpentine were thus formed. He suggested that sufficient magnesia for such a metasomatic change might be derived from the micas of the granites which underlie the Coast Ranges. Dr. Becker[2] later (1893), however, regarded some of the serpentine masses described in the quicksilver monograph as being altered peridotites.

In my field work at Mt. Diablo I came to the conclusion that the serpentine there is of igneous origin, as I found traces of the original pyroxene and olivine of the peridotite from which the serpentine was derived at several points. Dr. Charles Palache, in his bulletin on the rocks of the Potrero, San Francisco, likewise concluded that the Potrero serpentine is of igneous origin, and Dr. Ransome treated the serpentine of Angel Island

[1] Lithological Studies. Memoirs Mus. Comp. Zoöl., Vol. XI, Pt. I, pp. 129, 132, 142 and 158. (See also general discussion of the origin of peridotite, pp. 189–192.)

[2] Mineral Resources of the U. S. for 1892, DAY, p. 144.

ANALYSES OF SERPENTINES FROM THE COAST RANGES.

	No. 223, Mt. Diablo	No. 176, Mt. Diablo	No. 222, Mt. Diablo	Presidio	No. 78 *b*, Sulphur Bank	No. 181, Mt. Diablo	No. 110, New Idria	No. 78 *e*, Sulphur Bank	Angel Island
Si_2O	34.84	36.57	36.96	39.60	39.64	40.50	41.54	41.86	42.06
Cr_2O_3	0.68	0.33	0.78	.20	0.29	0.41	....	0.24	....
Al_2O_3	0.42	0.95	0.39	1.94	1.30	0.78	2.48	0.69	2.72
Fe_2O_3	6.08	7.29	5.00	....	....	4.01	....	....	
FeO	1.85	0.37	2.34	8.45	7.76	2.04	1.37	4.15	2.88
MnO	0.01	0.10	0.09		0.12	0.13	....	0.20	....
NiO	Trace	0.31	Trace	....	0.33	0.11	0.04	Trace	....
CaO	7.02	0.14	3.81	....	....	0.39	....	....	....
MgO	30.74	40.27	33.84	36.90	37.13	37.43	40.42	38.63	39.53
K_2O	0.07	Trace	0.14	....	....	0.16	....	....	....
NaO	0.42	0.31	0.34	....	....	0.28	....	....	....
H_2O above 100° C	15.72	12.43	14.02	12.91	12.91	10.94	14.17	14.16	12.04
Analyst	Melville	Melville	Melville	Easter	Melville	Melville	Melville	Melville	Ransome

Analyses Nos. 223, 222 176, and 181, from Mt. Diablo are taken from Bull. Geol. Society of America, Vol. II, pp. 383–414. The analyses of the Presidio rock is by J. D. Easter, and is from a report by Professor J. S. Newberry, in the Pacific Railroad report, Vol. VI, Part II, p. 11.

Analyses Nos. 78 *b*, 78 *e*, and 110 are taken from Monograph XIII, U. S. Geol. Surv., by G. F. Becker.

The analyses from Angel Island are taken from the Bulletin Department of Geology, University of California, Vol. I. p. 106.

as a metamorphosed igneous rock. The Angel Island rock was, however, considered as possibly being derived chiefly from diallage, but the analysis given shows clearly that no such derivation is possible. The table of analyses given below indicates how uniform in chemical composition the serpentines of the Coast Ranges are, and also that olivine or rhombic pyroxine must have been a prominent constituent of all of the original rocks from which the serpentines analyzed were derived.

The Franciscan or Golden Gate formation.—The metamorphic rocks of the Coast Ranges, and the associated cherts, sandstones, and shales, were formerly considered as of the age of the Knoxville beds; that is, lower Cretaceous. The more highly metamorphosed of these rocks are green amphibolite-schists, blue amphibolite-schists (glaucophane-schists), mica-schists, chlorite-schists, and various other schistose rocks. In my bulletin on Mt. Diablo, it was assumed that the red cherts or jaspers were silicified shales, and that these jaspers, together with the sandstones and schists associated with them, were the result of regional metamorphism of the Knoxville formation. Since that time it has apparently been shown, chiefly by Dr. H. W. Fairbanks, that these jaspers, associated sandstones, and schists are older than the Knoxville beds, and probably of Jurassic age. The best description of this series of rocks is that by Professor A. C. Lawson in his "Sketch of the Geology of the San Francisco Peninsula."[1]

One of the most interesting rocks of the series is the blue amphibole-schist, which is often found in croppings in or near serpentine masses. The blue amphibole is perhaps in part glaucophane, and these rocks have, therefore, generally been called glaucophane-schists. Dr. Ransome, in his study of the geology of Angel Island, found these schists at so many points on the border of serpentine masses that he concluded that they were contact metamorphic rocks. Professor Lawson, in the paper above referred to, considered the schists rich in amphibole to be metamorphosed volcanic material, but ascribed their origin, in

[1] Fifteenth Ann. Rept. U. S. Geol. Surv.

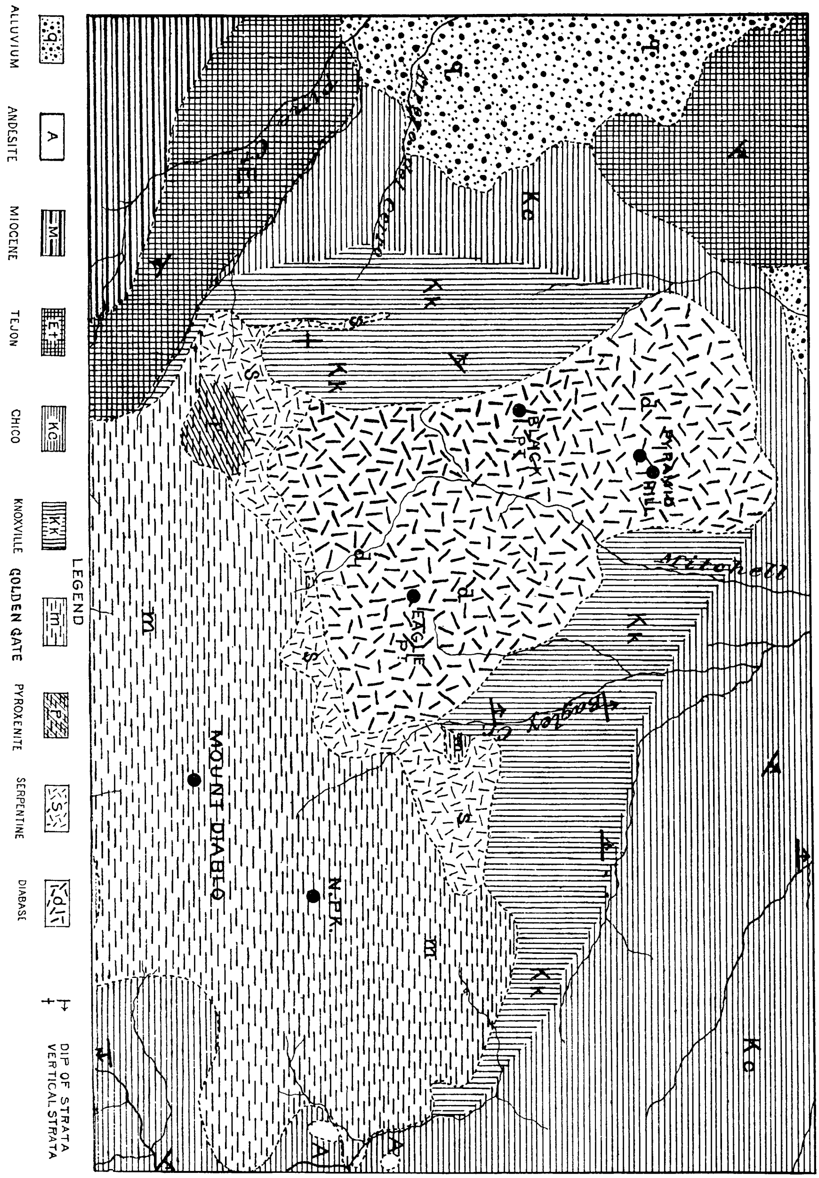
part at least, to contact metamorphism, and not regional metamorphism, believing that Dr. Ransome has established this in his bulletin on Angel Island. Professor Lawson seems to me to state the case very fairly. He writes as follows:

"In some few cases the schist areas have a very definite relation to dikes and laccolitic lenses of serpentine, and some of the most highly altered phases of schist that have been found, both of the micaceous and the blue amphibole varieties, have been taken from the immediate contact with the serpentine. In these cases there seems to be little doubt that we are dealing with a contact zone. In other cases, however, we have the immediate contact of serpentine and sandstone well exposed with no perceptible development of schist at the contact and little alteration of any kind appreciable to the unaided eye beyond a narrow zone of hornfels. It seems clear, therefore, that the metamorphic action of intrusive peridotite upon the rocks which it invades is not uniform, and the conditions which determine in some cases a maximum and in some cases a minimum of metamorphism are not yet known."

The point Lawson makes, that serpentine in many cases has merely hardened the sediments into which it is intruded and has not metamorphosed them, is perhaps of vital importance in discussing the origin of these schists. In the case of granitic intrusions into sediments, as everybody knows, there is always a zone of metamorphism all around the mass, and the conclusion that the granitic rock has caused this metamorphism appears to be absolutely demonstrated. When, therefore, we have an igneous intrusion which is bordered by schists on one side and by little altered sediments on the other, and if we know the latter to be older than the igneous mass and intruded by it, it is difficult to imagine conditions which cause such variable effects if we ascribe the formation of the schists to contact metamorphism. Such a case may be finely seen at Mt. Diablo. Here a dike of serpentine about 6.6^{km} long and 800^{m} wide extends in an east and west direction from the north flank of the mountain to near the east fork of Pine Creek. (See the geological sketch map of

Mt. Diablo.) On the south, this serpentine dike is flanked chiefly by the rocks of the Golden Gate series. On the north, at its east end, it is in contact with the shales of the Knoxville formation, and also, at its west end, in the upper drainage of the Arroyo del Cerro. At both points, it has effected no appreciable alteration of the Knoxville formation. In the Arroyo del Cerro drainage, the intrusive nature of this serpentine is beyond all question. The shales here stand nearly vertically with a strike in the neighborhood of the serpentine, approximately north and south, and a narrow apophysis of the main dike extends north into these shales for nearly one mile. This dike is cut by the Arroyo del Cerro and smaller streams, and in the ravines of these streams the dike nature of this serpentine apophysis can be clearly seen. The accompanying geological map shows the serpentine dike here described with the narrow apophysis extending north into the Knoxville shales. The area of the Golden Gate formation (*m*) in reality includes considerable masses of igneous rocks, chiefly metabasalt and serpentine. Thus the north peak is composed of a metabasalt which is said by Ransome to exhibit a spheroidal structure.

The Golden Gate series at Mt. Diablo, as elsewhere, however contains large amounts of igneous material which would more readily undergo recrystallization than the argillaceous and siliceous material of the Knoxville formation. It seems, therefore, possible that any contact metamorphism which the original peridotite of the serpentine dike might exert, would show more pronounced effects on the sediments of the Franciscan or Golden Gate series than on the material of the Knoxville formation. In addition to the large dike there are smaller masses of serpentine at various points along the flanks of the mountain. Glaucophane-schist is found near some of these serpentine croppings; in some cases exactly alongside of them; in other cases, it is not at the contact, but forms isolated croppings along with green amphibole-schists and micaceous schists. It would be unwise to insist that these schists have not resulted from the metamorphism of igneous material, by intrusive igneous masses, but it



GEOLOGIC MAP OF THE VICINITY OF MOUNT DIABLO, CALIFORNIA.

appears to me, in view of the foregoing facts, that it is yet to be demonstrated that these schists are the result of contact metamorphism of the peridotite intrusions. In any case, it seems clear that the glaucophane-schists and the green amphibole, garnet, and micaceous schists associated with them, are all caused by the same kind of metamorphism.

An investigation of the geology of the Bidwell Bar quadrangle, in the northern Sierra Nevada, has brought to light the existence of large areas of magnesian schists, associated with serpentine. These magnesian schists are composed of talc, chlorite, and various amphiboles, among which are prominent certain colorless amphiboles approximating to edenite and gedrite in composition. The microscopic investigation of these rocks clearly shows that these magnesian schists are alteration products of rocks of the same general nature as those which form the serpentine; that is to say, of rocks of the pyroxenite-peridotite family. The serpentine itself, no doubt, was largely formed from those masses rich in olive or rhombic pyroxene, and the various schists from aluminous pyroxenic facies of the magma. Many of these masses form croppings in and along serpentine masses, but they also form isolated areas of considerable extent. To conclude that any of these schists were formed by contact metamorphism would certainly in this case be erroneous, for not only can their composition be accounted for by supposing them to be alteration products of various pyroxenes, but their formation from these pyroxenes can in many cases be seen in the thin sections of the rocks.

If, as thought by Fairbanks, the Franciscan or Golden Gate series is older than the Knoxville, its generally hardened and altered character may have been the result of a pre-Knoxville metamorphism; for the beds, which have been determined as Knoxville, are nowhere much altered. It may then be advanced as a working hypothesis that the entire schist series of the Golden Gate formation was formed before the deposition of the Knoxville, and before the intrusion of at least some of the serpentine. If this be true, pebbles of some of these schists should

be found in the conglomerates of the Knoxville formation. Such conglomerates were observed at Knoxville, in Napa county. When making a geological map of the Knoxville quicksilver district for Dr. Becker, I collected some pebbles from these conglomerates, and later published[1] a few notes concerning them. As the characteristic fossil of the Knoxville formation (Aucella) occurs in this conglomerate, there can be no doubt concerning its age. The pebbles are of various porphyries, including soda-syenite porphyry and augitic porphyries and fine cherty pebbles, indistinguishable from the rocks called phthanites by Becker, radiolarian cherts by Lawson, and jaspers by Whitney and Fairbanks. A thorough investigation of these conglomerates will, perhaps, bring to light pebbles of some of these schists, the origin of which is ascribed to contact metamorphism and thus make certain their pre-Knoxville age. This being established, it would at least be certain that these rocks, if formed by contact metamorphism, were not formed by the serpentines which are found intruded into the Knoxville formation.

To the southeast of Coulterville,[2] in Mariposa county, and at other points, there are dikes of soda-feldspar, which are frequently intruded along the contact of serpentine masses with other rocks. These soda-syenite dikes, where altered, often contain blue amphibole in varying amount. Some of this may be primary, but part of it is secondary, The formation of glaucophane-schists (soda-amphibole) from crushed rocks containing much albite (soda-feldspar) seems quite possible. This is heightened by the finding by Ransome of white bunches composed of albite, in association with the glaucophane-schists on Angel Island. The suggestion of such an origin for the glaucophane-schists of the Coast Ranges should not, however, be taken too seriously.

Fossils being rare in the Golden Gate formation, all localities where remains have been found are worthy of note. About one mile (1.6 klms.) northeast of the summit of the north peak

[1] Am. Geol., Vol. XI, May 1893, p. 316.

[2] 17th Ann. Rept., U. S. G. S., Pt. I, p. 729.

of Mt. Diablo, in a ravine above the house of young Ben Dixen, fossils were found by Mr. F. M. Anderson, a student at the University of California, to whom I am indebted for the information. In company with Dr. Merriam, I visited this locality in 1897. We found more fossils there in thin, shaly layers in the hardened sandstone of the Golden Gate formation in a ravine above the house. This ravine heads just northeast of the north peak, and has a northeasterly course to about the fossil locality, where it turns sharply to the east. We collected some lamellibranchs here, which were not, however, specifically determinable. The sandstone is much intersected with fractures and can be readily broken out. This locality will probably afford more material, if carefully worked. Dr. T. W. Stanton, who saw Mr. Anderson's fossils, thought that the forms belonged to the *Cyprinidæ* or *Veneridæ*, but was unable to express a positive opinion concerning them.

The San Pablo formation. — At Kirker Pass,[1] north of the Mt. Diablo, south of the mountain at the Railroad Ranch reservoir, and at Corral Hollow, there are beds containing large amounts of volcanic detritus, as well as fossil shells and plant remains. The beds at Kirker Pass and Corral Hollow were first made known through the investigations of the State Geological Survey, under Professor Whitney. At a later date I visited the three localities above named and collected fossil plant remains at all of them, and fossil shells at two of them. The plant remains were studied chiefly by Professor Lesquereux, who assigned some of them to the Pliocene and others to the Miocene. The fossil shells were examined by Dr. Dall, who considered them to indicate a Pliocene age. Dr. Gabb had previously collected quite a series of fossil shells at Kirker Pass, and on that basis called the beds Pliocene.

In October 1897, in company with Dr. J. C. Merriam, I again visited Kirker Pass, and we collected there fossil shells and

[1] This pass is named after a Mr. Kirkwood, but the name Kirker having been used in geological literature for a long period, it is perhaps inadvisable to change the name to Kirkwood Pass.

plant remains, and I am indebted to Dr. Merriam for the following list of marine fossils from the Kirker Pass locality:

Fossils from San Pablo formation near Kirker Pass, north of Mt. Diablo, Contra Costa county, California. Collected by Gabb, Turner, and Merriam.

1. *Astrodapsis whitneyi* Rémond.
2. *Astrodapsis tumidus* (?) Rémond.
3. *Pseudocardium gabbi* Rémond.
4. *Ostrea Bourgeosii* Rémond.
5. *Ostrea titan* Rémond.
6. *Pecten pabloensis* Con.
7. *Pecten* (*Liropecten*) *crassicardo* Con.
8. *Cyrena californica* Gabb.
9. *Tapes staminea* Con.
10. *Tapes staleyi* (?) Gabb.
11. *Dosinia ponderosa* Gray.
12. *Gari alata* Gabb.
13. *Standella falcata* Gld.
14. *Saxidomus squalibus* Dash.
15. *Cardium blandium.*
16. *Macoma nasuta* (?) Con.
17. *Solen* sp.
18. *Mytilus* sp.
19. *Modiola* sp.
20. *Zirphæa* sp.
21. *Littorina remondi* Gabb.
22. *Littorina planaxis* Phil.
23. *Trophon ponderosum* Gabb.
24. *Ranella californica* Hds.
25. *Purpura saxicola* Val.
26. *Lunatia lewisii* Gld.
27. *Crypta grandis* Midd.
28. *Crepidula adunca* Sby.
29. *Calliostoma* n. sp. (?) Merriam.
30. *Ocinebra lurida* (?) Midd.
31. *Trochita filosa* Gabb.
32. *Trochita* n. sp. Merriam.
33. *Olivella boetica* Cpr.
34. *Bittium asperum* Cpr.
35. *Fusus* Gld.
36. *Purpura canaliculata* Duc.

This list contains 5 forms belonging to the Miocene, 2 (5?) forms belonging to the Merced formation, and 11 forms found elsewhere in the San Pablo formation.

There are 17 extinct and 14 living species, and the formation may, therefore, be regarded as of lower Pliocene age, on the basis of the ratio of the living and fossil forms.

In a recent paper,[1] on the Neocene sea-urchins, Dr. Merriam refers to the beds at Kirker Pass and similar beds at other points containing tuffs and volcanic ashes, as the "San Pablo formation." He considers the sea-urchins, belonging to the genus Astrodapsis, as particularly characteristic of this formation, inasmuch as he has not found them outside of it, and his information concerning the formations covers other localities besides those mentioned in this paper. This series of strata will then hereafter be spoken of as the San Pablo formation. In the bulletin, above referred to, Dr. Merriam concludes that this formation is of Middle Neocene age, including the top of the Miocene, and the base of the Pliocene. In my bulletin on Mt. Diablo, I called attention to the similarity of the plant forms in the San Pablo formation of the region about Mt. Diablo with the plant remains of the Auriferous gravels formation of the Sierra Nevada. The collections of the plant forms from the Coast Ranges are not sufficient to narrowly correlate the plant remains from the two regions, but it is clear that the marine fossil shells of the San Pablo formation furnish a more certain criterion for determining the exact horizon of the formation, than do the plant remains.

When the plant forms of the San Pablo formation have been collected in greater number and thoroughly studied a comparison can then be made between the floras of the Auriferous gravel series, and of the San Pablo formation, and the age of the auriferous gravels decided on that basis. As pointed out in an article on the Auriferous gravels,[2] it is certain that the fossil leaves collected from different localities in the Sierra

[1] Bull. Dept. Geol. Univ. of California, Vol. II, p. 116.

[2] American Geologist, Vol. XV, June 1895.

Nevada from the Auriferous gravels formation represent different horizons; nevertheless, no distinction has been made thus far by the palæobotanists, who have examined the different collections. It is, therefore, probable that, when studied, certain of these localities will be found to furnish a flora similar to that of the San Pablo formation, and other localities will furnish floras of a somewhat older date. In general, in recent years, the fossil plant remains of the auriferous gravels have been called Upper Miocene. It is more than likely that some of these localities are of Pliocene age. There is published herewith, a section of the San Pablo formation at Kirker Pass, north of

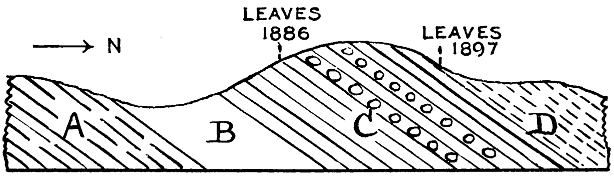


FIG. 1.— Section of the San Pablo formation on the Hyde Ranch, north of Mt. Diablo. The horizontal extent of the section is about 600 meters. The section, however, does not necessarily include the top or the base of the formation at this point. *A* = White shales and rhyolitic tuff; *B* = Fossiliferous sandstone; *C* = Andesitic tuff, sandstone, and conglomerate; *D* = Shale and pumice.

Mount Diablo. The horizontal extent of the beds shown in the section is 600 meters. The beds dip uniformly to the north at an angle of about 35° and thus have a thickness normal to the bedding of about 350 meters, or about 1150 feet. The section given above (Fig. 1) is drawn without reference to scale, merely to show the relations of the different members of the formation. The basal portion (*A*) of the section is composed of fine-grained white shales, and volcanic detritus, which Dr. Merriam has noted at other localities in the formation, and he regards this as its base. An optical examination of volcanic glass which forms certain layers in these white shales, shows the glass to be of rhyolitic composition. There is given below an analysis, No. 399, of a specimen of this glass. This analysis shows that the rhyolite has undergone leaching, having lost both alkali and silica, as is

very frequently the case with layers of volcanic glass and pumice. Overlying this basal volcanic series are some sandstone beds (*B*), which have offered the majority of the marine fossil shells from this locality. Lying upon fossiliferous sandstones are a set of blue beds (*C*), composed of volcanic conglomerate, tuff and sandstone. The tuffs and volcanic conglomerates are derived from andesite, containing hornblende and pyroxene. These andesitic tuff beds contain abundant silicified wood, and the first list of fossil leaves given below collected in 1886, came from a fine layer in this tuff series.

These leaves were studied by Lesquereux, who published a list of the species identified in the proceedings of the U. S. National Museum (Vol. XI, 1889, p. 35), as follows.

Fossil leaves from the San Pablo formation on the Hyde Ranch, collected in 1886.

Diospyros virginiana 1, var. turneri, Lx.
Magnolia californica Lx.
Laurus, cf. *canariensis* Heer.
Virburnum, cf. *rugosus* Pers.
Vitis, sp. (?).

These are considered to be probably Pliocene, although on page 11 of the same publication, the same collection is referred to the Upper Miocene. These leaves come from a fine layer in the blue andesitic sandstones which form a higher horizon than the bed which afforded the most of the fossil shells given in the previous list by Dr. Merriam.

The leaves collected in October 1897, came from a bed conformably overlying the blue andesitic sandstones, and underlying the volcanic pumice represented by specimens 345 (Series D). Immediately underlying the leaf layer, is a light colored layer, containing specks of pumice in which are fossil shells. One of these, is an Astrodapsis, as determined by Dr. Merriam, which is considered as characteristic of the San Pablo formation. This second set of leaves came from a higher horizon of the San Pablo formation than those collected in 1886. The leaves collected in 1897 were referred to Professor F. H. Knowlton

of the National Museum, who reports as follows concerning them:

Six species of plants are represented:

Fern, probably *Pteris*, but very fragmentary.
Populus, female Catkin.
Alnus, fruits and leaves.
Castanea, sp. leaf.
Vaccinum, sp. single small leaf.
Arbutus, sp. Numerous well-preserved leaves and fragments.

I have not been able to identify any of the above mentioned material with anything from California. The forms all have a very modern aspect, the more abundant being the Arbutus, which is close to the living form.

As to the age, I do not think there can be any doubt about their being Pliocene. They certainly cannot be older.

The conclusion of Professor Knowlton that the plant remains in 1897 are certainly not older than Pliocene, would not appear to conflict with the conclusion of Merriam as to the Middle Neocene age of the formation as a whole, inasmuch as these leaves came from near the top of the formation, as exposed near Kirker Pass. Overlying the plant remains above noted, are some layers of volcanic pumice (*D*), of which specimens were collected. An examination of this material under the microscope shows that it has been much altered by infiltrating waters, but that the glass has a rhyolitic composition, as indicated by its low index of refraction. A chemical analysis of one specimen, No. 345, shows, as does the analysis of No. 399, that the pumice has undergone leaching, resulting in a loss of silica and alkali. All of the plant remains obtained by myself at Kirker Pass came from the Hyde Ranch, and were collected in a field west of the road from Cornwall to Summersville. The locality of 1897, is on the north slope of a low hill, and about 430 meters south of the house of George South.

The San Pablo formation, at Corral Hollow, has afforded nineteen species of fossil plants. A few of which have been identified in the Auriferous gravels flora. The plant beds at Corral Hollow, from which the specimens came which I collected, underlie andesitic tuffs, and conglomerates, which are

quite like those of the San Pablo formation, in the Mount Diablo quadrangle. It is, therefore, likely that the Corral Hollow plant remains represent a somewhat older horizon than those collected near Kirker Pass.

ANALYSES OF RHYOLITIC TUFF FROM THE SAN PABLO FORMATION, BY WILLIAM VALENTINE.

	No. 339. Near base of San Pablo	No. 345. Near top of San Pablo
SiO_2	63.28	63.28
CaO	1.90	1.18
K_2O	2.44	0.78
Na_2O	1.82	0.56

The Merced formation of Lawson,[1] which has been referred to, is probably younger than the San Pablo and of Upper Pliocene age. The Merced formation is named from Merced Lake, in the vicinity of which the beds are extensively developed. It is probably identical with the Wild Cat series of Humbolt county, described by Lawson,[2] in which case the latter name should be dropped. As pointed out by Lindgren,[3] the correlation by Lawson on the Merced series with the Auriferous gravels formation is probably incorrect. It is far more likely that the Auriferous gravels series is in part contemporaneous with the San Pablo formation, and in part older than that formation.

H. W. TURNER.

[1] Bull. Dept. Geol. University of California, Vol. I, pp. 142–149.

[2] Bull. Dept. Geol. University of California, Vol. I, pp. 255–263.

[3] JOUR. GEOL., Vol. IV, pp. 904, 905.